

243217 to Hiroyuki et al. ("Hiroyuki"). Claim 5 is rejected under 35 U.S.C. §103(a) as being unpatentable over Masahiro, Osamu and Hiroyuki in view of U.S. Patent No. 6,445,114 to Kurokawa et al. ("Kurokawa"). Claim 7 is rejected under 35 U.S.C. §103(a) as being unpatentable over Masahiro and Osamu in view of Japanese Patent Publication No. 2001-118488 to Hisashi ("Hisashi"). Applicants amend independent claims 1 and 17 to further clarify the nature of their invention, and respectfully traverse the rejections of claims 1 - 9 under 35 U.S.C. §103(a).

In amended independent claim 7, Applicants claim:

1. A diamond electron emission device comprising a light emitting device for irradiating light to a cathode, wherein at least an electron emission face of said cathode is made of diamond and the energy of light emitted from the light emitting device is limited to 5.4 eV or less.

(Emphasis added).

Masahiro discloses a vacuum tube device having an optically excited electric field emission P-type semiconductor cathode 107 formed in proximity to a luminous part 103, and an anode electrode 110 positioned over the cathode 107(see, e.g., abstract of Masahiro). When an electric field is applied to the cathode 107 and light is radiated from the luminous part 103, electrons of the cathode are excited from a low energy state to a high energy state, thereby lowering the electric field required for electron emission. Masahiro teaches that this effect is achieved as follows: "when a semiconductor [cathode] is irradiated with light having energy equal to or higher than the energy gap of the semiconductor, an electron-hole pair is produced." (see, e.g., page 3, line 45 of Masahiro, emphasis added).

Applicants claim a diamond electron emission device including a light emitting device for irradiating a cathode. At least a face of the cathode is made of diamond, and the light emitted by the light from the light emitting device is limited to 5.4 eV or less. The energy (or band) gap for diamond is known to be approximately 5.5 eV.¹ Therefore, and in sharp contrast to Masahiro, Applicants' claim a diamond electron emission device including a light emission device that radiates at an energy that is less than the energy gap of the cathode material.

The Examiner acknowledges that Masahiro fails to teach a cathode comprising an electron emission face made of diamond, but suggests that this deficiency is overcome with the addition of Osamu. Osamu discloses a field emission type light-electric current converter comprising a plurality of small, needle-shaped electron emitting sources 2 that face a current collecting electrode 3 over a gap (see, e.g., FIG. 1 of Osamu). A light source irradiates tip ends of the electron emitting sources 2, which affects the current produced at the tip ends and collected by the current collecting electrode 3. The Examiner suggests that Osamu at paragraph [0004] discloses that at least an emission face of each electron emitting source 2 is made of diamond.

Osamu teaches that a semiconductor emission face may be provided on an electron emission source in order to provide an increase in photoconductivity:

[Regarding] an electron emission source, metals do not have an effect of photoconduction, and thus an insulating or semi-insulating material is used. (page 3, line 25 of Osamu).

[When] the tip of a needle made of a semiconductor having a substantially insulating property is irradiated with light, the photoconductivity instantaneously increase to markedly increase the amount of current (page 2, line 2 of Osamu, emphasis added).

¹ See, e.g., <http://newton.ex.ac.uk/research/qsystems/people/sque/diamond/>

In sharp contrast to Osamu, both Masahiro and the present invention has as an object to lower the operating voltage of an electron emitter. Applicant discovered that this object could be accomplished by exciting electrons in a diamond face to a higher level than a conduction band 21 of diamond, which is also higher than a vacuum level 25 (see, e.g., page 10, lines 2 - 6 of Applicants' specification and Applicants FIG. 4). As Osamu fails to teach a structure for lowering operating voltage, Applicants respectfully submit that one skilled in the art at the time of the invention would not have concluded that incorporating a semiconductor tip on the cathode 107 would lead to a lowering of operating voltage based on Osamu, and therefore would not have combined Masahiro with Osamu in order to arrive at the invention as presently claimed in amended independent claim 1. Moreover, like Masahiro, Osamu does not appear to teach or suggest a light emission device that radiates at an energy that is less than the energy gap of the cathode material.

For at least the above-argued reasons, Applicants submit that amended independent claim 1 is not made obvious by any of the cited references, either alone or in combination, and that claim 1 therefore stands in condition for allowance. As amended independent claim 17 substantially includes the elements of allowable independent claim 1 above-argued as distinguishing independent claim 1 over the cited references, Applicants reapply these arguments to amended independent claim 17 and submit that independent claim 17 is also allowable for at least the same reasons. As each of claims 2 - 16, 18 and 19 depends either directly or indirectly from one of allowable claims 1 and 17, Applicants further submit that dependent claims 2 - 16, 18 and 19 are also allowable for at least this reason.

Therefore, Applicants respectfully request that the rejection of claims 1 - 19 under U.S.C. §103(a) be withdrawn.

New Claims

Applicants add new claims 20 - 24. As each of new claims 20 - 24 depends from one of allowable claims 1 and 17, Applicants submit that new claims 20 - 23 are also allowable for at least this reason.

CONCLUSION

Each and every point raised in the non-final Office Action mailed April 2, 2008, have been addressed on the basis of the above amendments and remarks. In view of the foregoing it is believed that claims 1 - 24 are in condition for allowance, and it is respectfully requested that the application be reconsidered and that all pending claims be allowed and the case passed to issue.

If there are any other issues remaining which the Examiner believes could be resolved through a Supplemental Response or an Examiner's Amendment, the Examiner is respectfully requested to contact the undersigned at the telephone number indicated below.

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Respectfully submitted,

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